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BeanAir

APPLICATION NOTE

Structural Health monitoring on bridges

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V1.0	10/09/2011	Christophe DONTEGREUIL	First version of the document
V1.1	29/04/2012	Maneli PARSY	Shift 1.0->1.1 Technical notes Hyperlink added
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1. TECHNICAL SUPPORT

For general contact, technical support, to report documentation errors and to order manuals, contact ***BeanAir Technical Support Center*** (BTSC) at:
tech-support@beanair.com

For detailed information about where you can buy the BeanAir equipment/software or for recommendations on accessories and components visit:

www.beanair.com

To register for product news and announcements or for product questions contact BeanAir's Technical Support Center (BTSC).

Our aim is to make this user manual as helpful as possible. Please keep us informed of your comments and suggestions for improvements. BeanAir appreciates feedback from the users.

2. VISUAL SYMBOLS DEFINITION

Visual	*Definition*
	***Caution or Warning** – Alerts the user with important information about BeanAir wireless sensor networks (WSN), if this information is not followed, the equipment /software may fail or malfunction.*
	***Danger** – This information MUST be followed if not you may damage the equipment permanently or bodily injury may occur.*
	***Tip or Information** – Provides advice and suggestions that may be useful when installing BeanAir Wireless Sensor Networks.*

3. ACRONYMS AND ABBREVIATIONS

AES	Advanced Encryption Standard
CCA	Clear Channel Assessment
CSMA/CA	Carrier Sense Multiple Access/Collision Avoidance
GTS	Guaranteed Time-Slot
kSps	Kilo samples per second
LLC	Logical Link Control
LQI	Link quality indicator
LDCDA	Low duty cycle data acquisition
MAC	Media Access Control
PAN	Personal Area Network
PER	Packet error rate
RF	Radio Frequency
SD	Secure Digital
SSD	Smart shock detection
WSN	Wireless sensor Network

4. RELATED DOCUMENTS

In addition to this User manual, please consult the application notes & technical notes mentioned below:

4.1 APPLICATION NOTES

Nom du document	*Produits concernés*	*Description*
AN_RF_007 : Beanair_WSN_Deployment"	All BeanAir products	Wireless sensor networks deployment guidelines
AN_RF_006 – „How to extend your wireless range"	All BeanAir products	A guideline very useful for extending your wireless range
AN_RF_005 Ver 1.0- BeanGateway® & Data Terminal Equipment Interface	BeanGateway®	DTE interface Architecture on the BeanGateway®
AN_RF_004 V1.0-1. Coexistence And Interferences@2.4GHz	All BeanAir products	Coexistence & interferences of different RF technologies in the 2.4 GHz frequencies band.
AN_RF_003 V1.1 IEEE 802.15.4 2.4 GHz Vs 868 MHz (English)	All BeanAir products	Comparison between 868 MHz frequency band and a 2.4 GHz frequency band.

4.2 TECHNICAL NOTES

Document name	Concerned products	Description
TN_RF_010 – « BeanDevice® Power Management »	All the BeanDevice®	This technical note describes the sleeping & active power mode on the BeanDevice®.
TN_RF_009 – « BeanGateway® management on LAN infrastructure »	BeanGateway®	BeanGateway® integration on a LAN infrastructure
TN_RF_008 – "Data acquisition modes available on the BeanDevice®"	All the BeanDevice®	Data acquisition modes available on the BeanDevice®
TN_RF_007 – "BeanDevice® DataLogger User Guide "	All the BeanDevice®	This document presents the DataLogger feature on the BeanDevice®
TN_RF_006 – "BeanDevice® wireless network association"	All the BeanDevice®	Description of the BeanDevice® network association
TN_RF_005 – "Pulse counter & binary data acquisition on the BeanDevice® SUN-BN"	BeanDevice® SUN-BN	This document presents Pulse counter (ex: energy metering application) and binary data acquisition features on the BeanDevice® SUN-BN.
TN_RF_004 - Ambient Light sensor technical specifications	BeanDevice® SUN-XX (Ecosensor)	Technical description of the Ambient light sensor available on the BeanDevice® SUN-XX products
RF_TN_003 - Wireless Network capacity	All the products	Network capacity characterization of Beanair Wireless Sensor Networks
RF_TN_002 - Current consumption in active & sleeping mode	BeanDevice®	Current consumption estimation of the BeanDevice in active and sleeping mode
RF_TN_001 - Wireless range benchmarking	BeanDevice®	Wireless range benchmarking of the BeanDevice®

5. AIM OF THE DOCUMENT

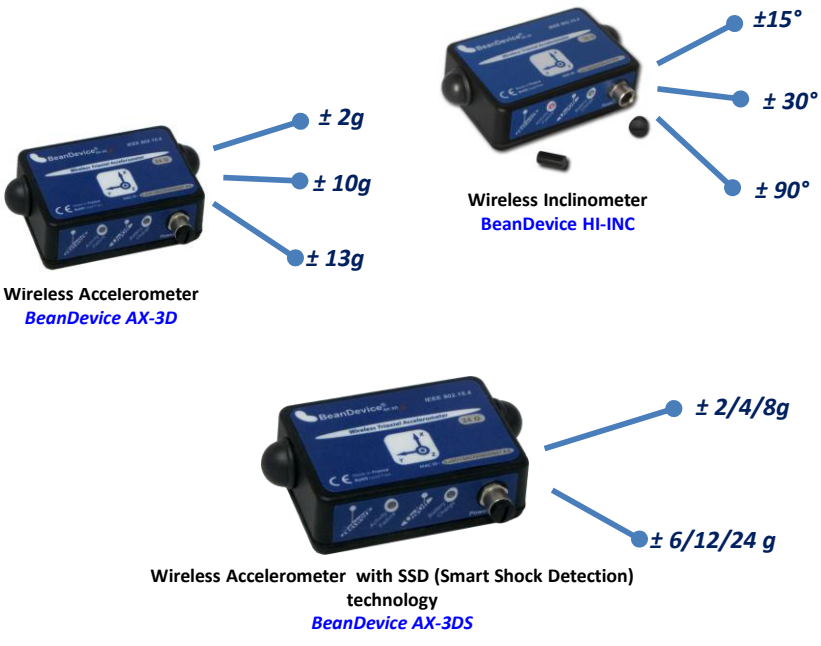
Bridges, which are the key components of any transportation system, have expected life cycles as long as 50 or 100 years, it is however not uncommon to see even older structures which are still in service. During its long service life a bridge would be subject to aging processes, harsh environmental conditions and excessive loads, leading to deterioration. Consequences of impaired physical condition can be as severe as the collapse of the structure, causing great financial loss or even casualties, but even major protective maintenance and upgrading works or replacement of the bridge are expensive and troublesome. Thus, it is important to have updated information on structural condition and performance of bridges in order to early detect any worrying signs of decline and undertake protective countermeasures. Transportation infrastructure authorities have long recognized the need to keep their bridges healthy and to this end have implemented various inspection and management programs. The current health monitoring practice is primarily based on visual inspection. However, due to high manpower demand such inspections cannot be performed frequently. Other drawbacks of visual inspection based condition assessment include inaccessibility of critical parts of the structure and lack of information on actual loading. These shortcomings lead to subjective and inaccurate evaluations of bridges safety and reliability. As a result some bridges may be retrofitted or replaced, while in fact they are sound; on the other hand, existing damages in other bridges may not be identified until they become expensive to repair or dangerous for structural integrity. An alternative to the periodic visual inspection can be continuously operating instrumented structural health monitoring (SHM) systems. The recent developments in sensor technology, especially when wireless technology is considered have opened up new gates in terms of health monitoring and preemptive fault detection. Beanair®'s wireless sensor technology offers great reliability, versatility, maintainability and easy to deploy and configure technology.

The aim of this document is to overview Beanair® products suited for bridge monitoring, their deployment, as well as their capacity and limits by overviewing various data acquisition modes available on each BeanDevice®.

6. SMARTSENSOR PRODUCTS PRESENTATION

The Smartsensor® product line is declined as the following:

- ✓ ***BeanDevice® AX-3D***: 3-axis wireless accelerometer for vibration measurement
- ✓ ***BeanDevice® AX-3DS***: 3-axis wireless accelerometer for shock measurement
- ✓ ***BeanDevice® HI-INC***: 1 or 2-axis wireless inclinometer for tilt measurement



Click here to see the Video of the BeanDevice® AX-3D

Click here to see the video of the BeanDevice® HI-INC

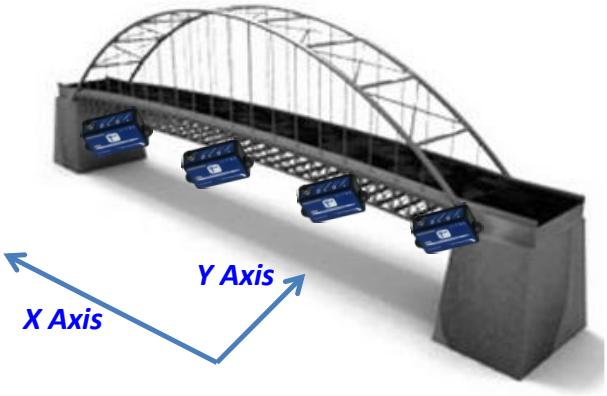
Click here to see the video of the BeanGateway® (Outdoor version)

Click here to see the video of the BeanGateway® (Indoor version)

7. WIRELESS SENSORS FOR BRIDGE MONITORING

7.1 TILT MEASUREMENT

The following pictures shows how the Beandevice® can be mounted on a bridge. In this particular case the mounting was done by using aluminum coil tape and epoxy glue.



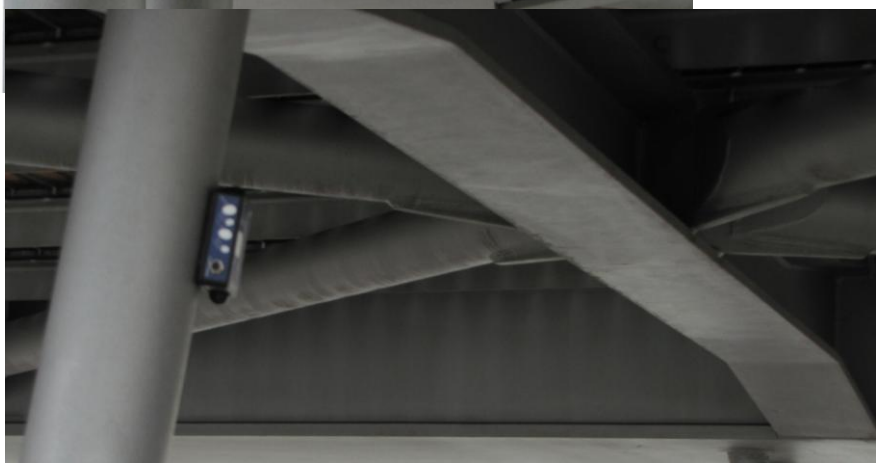
Tilt Measurement on bridge (max measurement range +/-1,5°)

7.1.1 BeanDevice® HI-INC configuration

BeanDevice® HI-INC configuration for Tilt measurement on a Bridge		
Recommended Beandevice® version	BeanDevice® HI-INC ±15°	
Data acquisition mode used	Slow monitoring	LDCDA (Low Duty Cycle Data Acquisition) with a duty cycle of: 10 seconds to 1 hour
	Fast monitoring	Streaming or Streaming Packet mode : 1 Hz to 40 Hz
Maximum inclination range	± 1.5°	
Maximum wireless range	300 to 500 meters The user can extend the wireless range by using a high gain and directionnal antenna on the BeanGateway®.	
Battery Autonomy	Slow monitoring	2 to 6 months
	Fast monitoring	18hours maximum
Number of axis	1 or 2	
Number of Beandevice® on the same wireless sensor network	Slow monitoring	45 maximum
	Fast monitoring	Please refer to the Technical Note: ***"TN_RF_003 Wireless Network Capacity"***

7.2 VIBRATION ANALYSIS

Vibration measurement on the pillar



7.2.1 BeanDevice® AX-3D configuration

BeanDevice® AX-3D configuration for Vibration measurement on a Bridge		
Beandevice® technology used	BeanDevice® AX-3D ±2g , ±10g , ±13g	
Data acquisition mode used	Streaming Packet mode with a sampling rate of 200 Sps (samples per second) maximum	
Maximum Vibration range	± 2g	
Maximum wireless range	300 to 500 meters The user can extend the wireless range by using a high gain and directionnal antenna on the BeanGateway®.	
Battery Autonomy	Fast monitoring	18 hours maximum The user can extend the battery autonomy by adding an external battery and a solar panel.
Number of axis	3 axis	
Number of Beandevice® on the same wireless sensor network	4, if the sampling rate is 200 Sps on each BeanDevice (3 axis activated) Please refer to the Technical Note: ***"TN_RF_003 Wireless Network Capacity"***	

7.3 SINKING AND CRACK DETECTION ON BRIDGE

The BeanDevice® AX-3DS can be used for detecting a shock event during a train passage on a bridge. This product is ideal for analyzing the shock profile on the bridge foundation.

7.3.1 Advantages of SSD Technology (Smart shock Detection)

The Beandevice® AX-3DS offers the following advantages:

<table>
<tr><td>SSD (Smart shock detection) Technology</td><td colspan="2">The BeanDevice® will wake up when a shock threshold is detected. The user can fix by himself the shock threshold and time hysteresis.
For further information about the SSD (Smart Shock Detection) measurement mode, read the technical note TN_RF_008 "Data acquisition modes available on the BeanDevice®"</td></tr>
<tr><td>Ultra Low Power wireless sensor</td><td colspan="2">Power Consumption in Sleeping step :
Power Consumption in sleeping mode with SSD (Smart Shock Detection) activated:</td></tr>
<tr><td></td><td>Accelerometer Bandwidth during Sleeping Mode</td><td>BeanDevice® Power Consumption</td></tr>
<tr><td></td><td>0 Hz</td><td>8µA</td></tr>
<tr><td></td><td>0,5 Hz</td><td>21 µA</td></tr>
<tr><td></td><td>2Hz</td><td>50 µA</td></tr>
<tr><td></td><td>1 Hz</td><td>31 µA</td></tr>
<tr><td></td><td>5Hz</td><td>78 µA</td></tr>
<tr><td></td><td>10Hz</td><td>130 µA</td></tr>
<tr><td></td><td>50 Hz</td><td>302 µA</td></tr>
<tr><td></td><td>100 Hz</td><td>308 µA</td></tr>
<tr><td></td><td>400 Hz</td><td>343µA</td></tr>
<tr><td></td><td>1000 Hz</td><td>413 µA</td></tr>
<tr><td>False alarm management</td><td colspan="2">For avoiding false alarms, the user can fix by himself the time hysteresis.</td></tr>
</table>

7.3.2 BeanDevice® AX-3DS configuration

BeanDevice® AX-3DS configuration for Shock measurement on a Bridge	
Beandevice® technology used	BeanDevice® AX-3DS
Data acquisition mode used	SSD (Smart Shock Detection) measurement mode. The Beandevice® will wake up if a shock profile is detected.
Maximum wireless range	300 to 500 meters The user can extend the wireless range by using a high gain and directional antenna on the BeanGateway®.
Number of axis	3 axis
Number of Beandevice® on the same wireless sensor network	20 to 50 BeanDevice®

8. WIRELESS SENSOR NETWORK TOPOLOGY

8.1 OUT OF THE BOX WSN WITH ETHERNET CONNECTION

The most basic/minimal WSN consists in deploying a local network that can be monitored through a local PC server/ embedded PC. In this case the PC is either directly connected to the BeanGateway® (in case of a mono-gateway architecture) or to a switch that is connected to multiple gateways through an Ethernet connexion.

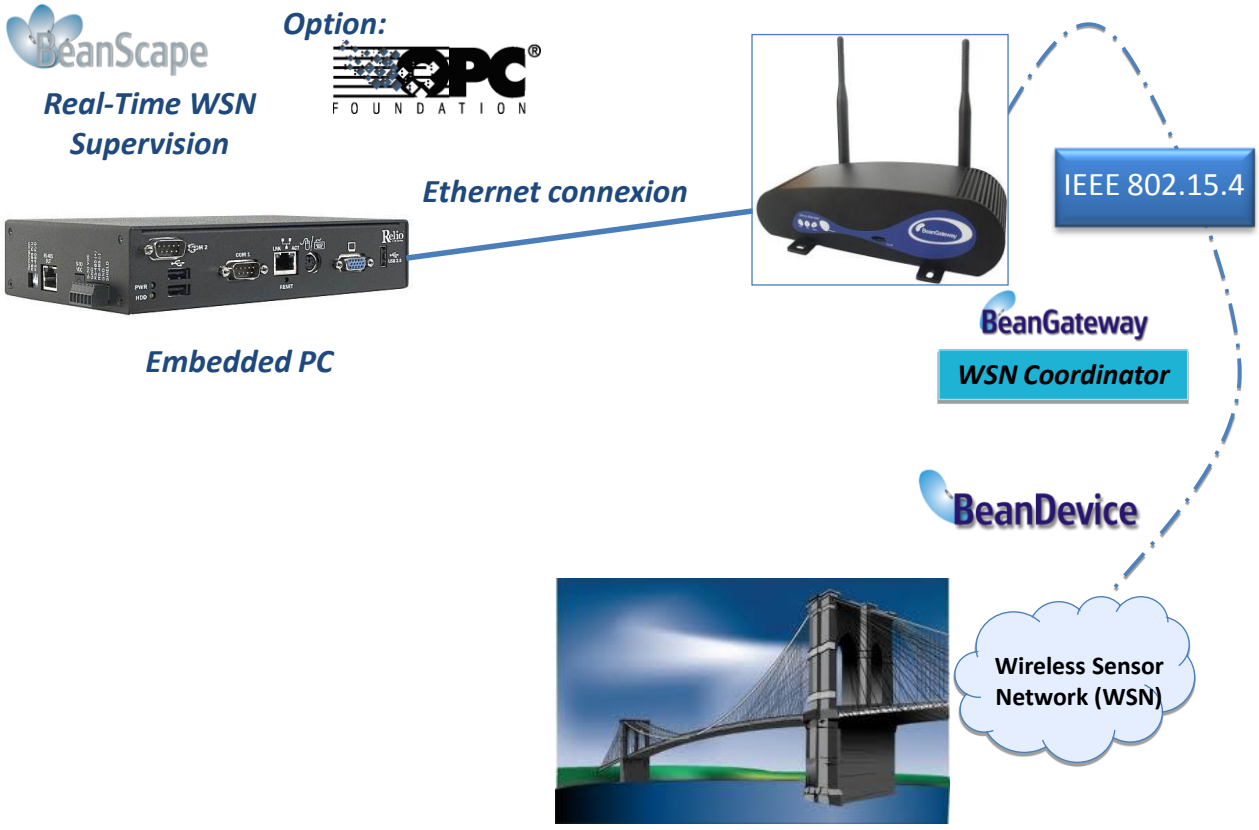


Figure 1: Network Topology with 1 BeanGateway® connected to the BeanScape®

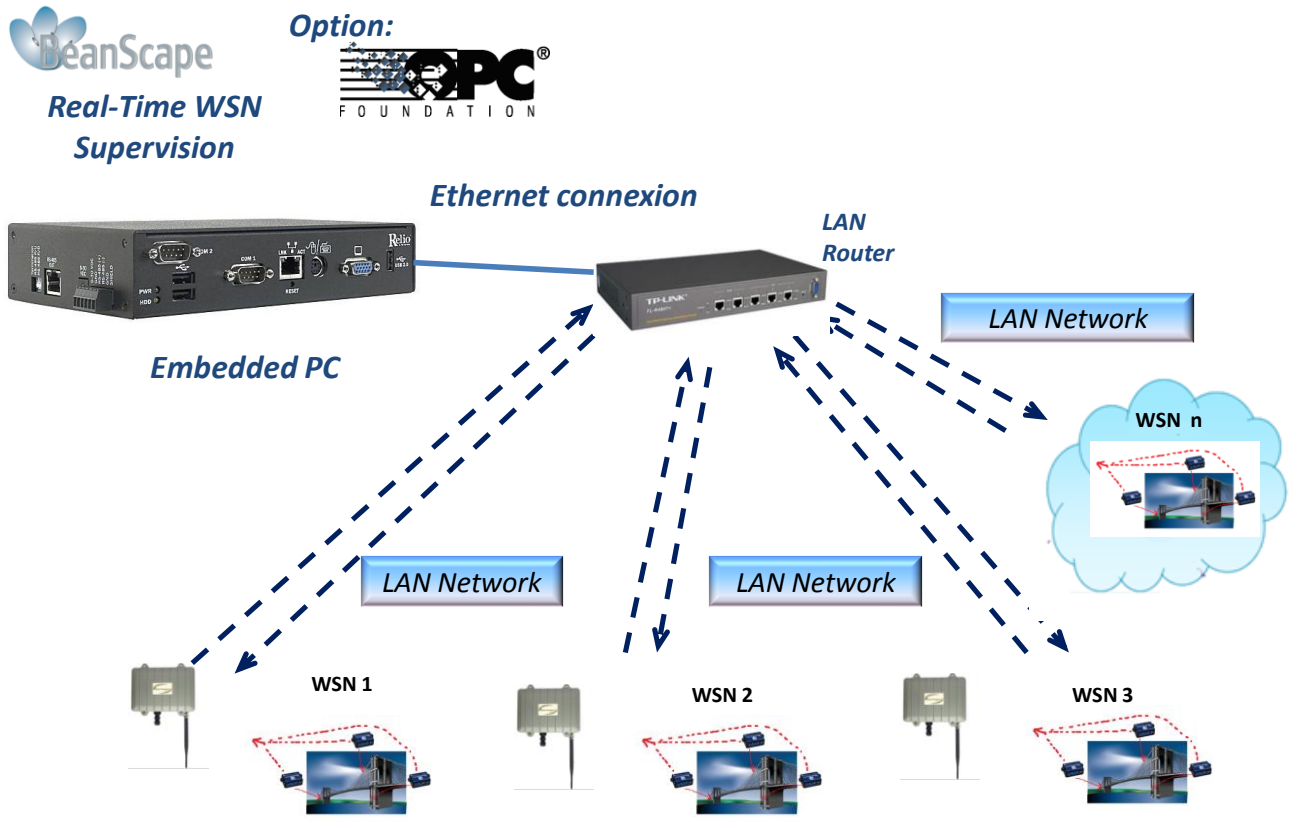


Figure 2: Network Topology with several BeanGateway® connected to the BeanScape®

8.1.1 Hardware Requirements

Embedded PC	Use a ruggedized "Embedded PC" with Windows Embedded or Windows XP software. The BeanScape® is not compatible with Linux or Ubuntu OS.
BeanGateway® version	Outdoor version of the BeanGateway® with Ethernet connexion

8.1.1 Network architecture performances

FEATURES	
Local /Cloud supervision software	BeanScape®(Local supervision software)
Network Reliability	High
Network installation complexity	Low
Compatibility with streaming, streaming packet and SSD Data acquisition mode	Yes

8.2 WSN WITH GSM/GPRS CONNECTION AND ONESENSE WEBSERVER

OneSense® Webserver/Webportal is available for customers based in FRANCE and will soon be available to export as well. The GSM/GPRS architecture is well suited for low rate data transmission. In addition, the OneSense® Webser/Webportal offers a highly customizable GUI together with numerous web services and functionalities that blend into your already existing IT platforms and infrastructures.

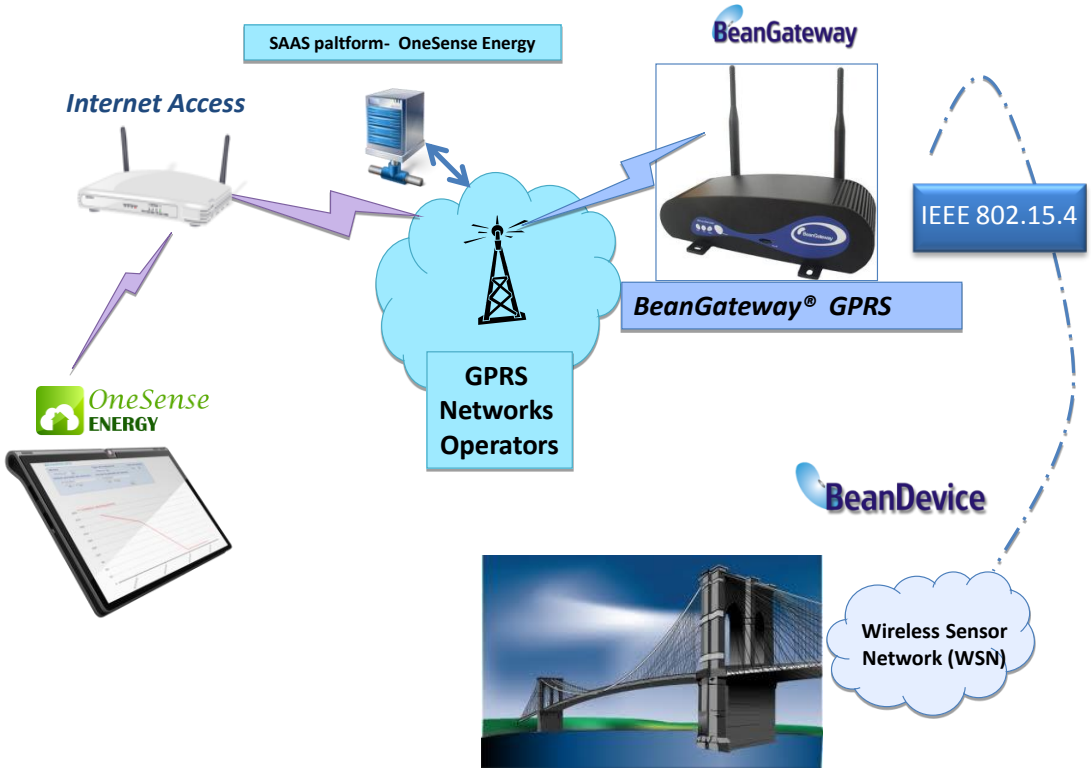


Figure 3 : WSN with GSM/GPRS Network

GSM/GPRS Network is not compatible with streaming, streaming packet and SSD (Smart shock detection) data acquisition mode.

8.2.1 Hardware Requirements

OneSense®	OneSense® Energy Webserver
BeanGateway® version	Outdoor version of the BeanGateway® with GSM/GPRS connectivity

The BeanGateway® GSM/GPRS can not operate without OneSense® Energy Webserver.

8.2.1 Network architecture performances

FEATURES	
Local /Cloud supervision software	Cloud solution(OneSense® Energy)
Network Reliability	Medium
Network installation complexity	Medium
Compatibility with streaming, streaming packet and SSD Data acquisition mode	No

8.3 WSN WITH 3G CONNECTION

8.3.1 Hardware Requirements

The 3G network is well suited for high rate data transmission (Streaming & Streaming Packet mode). The minimum requirements for implementing a 3G connection are:

3G Gateway	***TECHNOLOGY*** • HSUPA with fallback to: HSDPA, UMTS, EDGE ***Bands*** Tri-Band UMTS/HSDPA/HSUPA: 850, 1900, 2100 MHz Or Quad-Band UMTS/HSDPA/HSUPA: 850, 900, 1900, 2100 MHz ***HOST INTERFACES*** Ethernet: 10/100 BASE-T RJ-45 ***APPLICATION INTERFACES*** TCP/IP, UDP/IP, DHCP, HTTP, SNMP, SMTP, SMS, MSCI
ADSL Modem	ADSL Modem with NAT Configuration software
BeanGateway®	Ethernet version of the BeanGateway®

For further information about the 3G Network configuration, please read the technical note TN_RF_009 "BeanGateway® management on a LAN infrastructure".

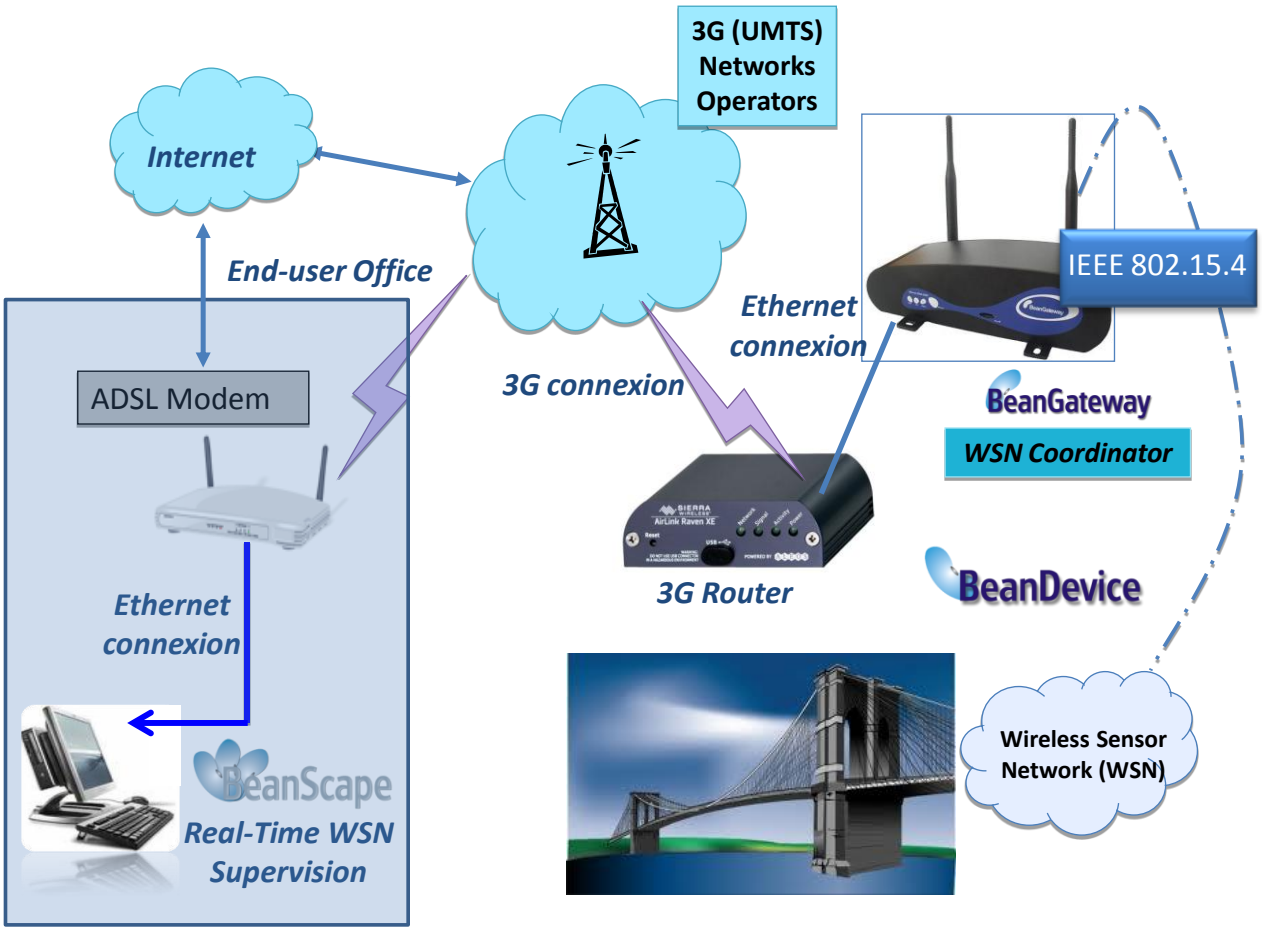


Figure 4 : WSN with 3G Network

8.3.2 Network architecture performances

FEATURES	
Local /Cloud supervision software	Local (BeanScape®)
Network Reliability	***Low*** : Beanair cannot make a guarantee the 3G Quality of Services (QOS)
Network installation complexity	High
Compatibility with streaming, streaming packet and SSD Data acquisition mode	Yes

8.4 VARIOUS DATA ACQUISITION MODES AVAILABLE ON DIFFERENT PLATFORMS

DATA ACQUISITION MODE	*GSM/GPRS*	*3G*	*ETHERNET*
Low Duty Cycle Data Acquisition (LDCDA)	Yes, with a minimum duty cycle of 30s	Yes	Yes
Alarm & Survey mode	Yes, with a minimum duty cycle of 30s	Yes	Yes
Math Mode	No	Yes	Yes
Streaming Packet Mode	No	Yes	Yes
Streaming Mode	No	Yes	Yes
Shock detection	No	Yes	Yes

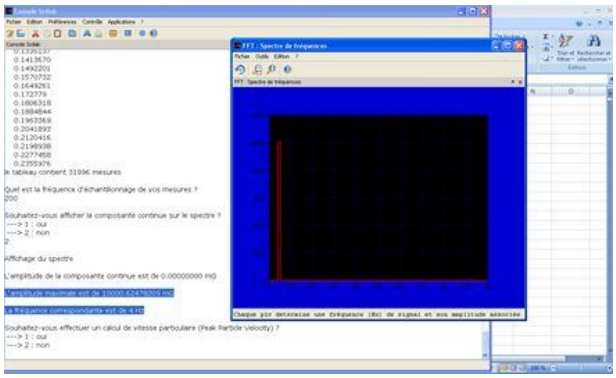
9. SCILAB SCRIPTS

Created in 2003 by INRIA (the French National Institute for Research in Computer Science and Control), the Scilab Consortium joined the Digiteo Foundation in July 2008.

The Scilab Consortium, which includes industrials and academics, pursues the ambition of making Scilab technology the free reference in numerical computation.

Scilab is free open source software with a GPL compatible license**.** Thus, the Scilab Consortium is involved in the Open Source world in different ways.

All Scilab libraries are free with accepted and recognized licenses by the FLOSS community (Free Open Source Software). The license is one of the key criteria for the selection of a library of Scilab.



Beanair provides for free PPV (Peak Particle Velocity) and FFT (Fast Fourier Transform) scripts for vibration measurement , the following video shows how Scilab scripts are used with our equipment:

Click here to see cilab Script Video

10. HOW TO EXTEND THE AUTONOMY OF YOUR BEANDEVICE®

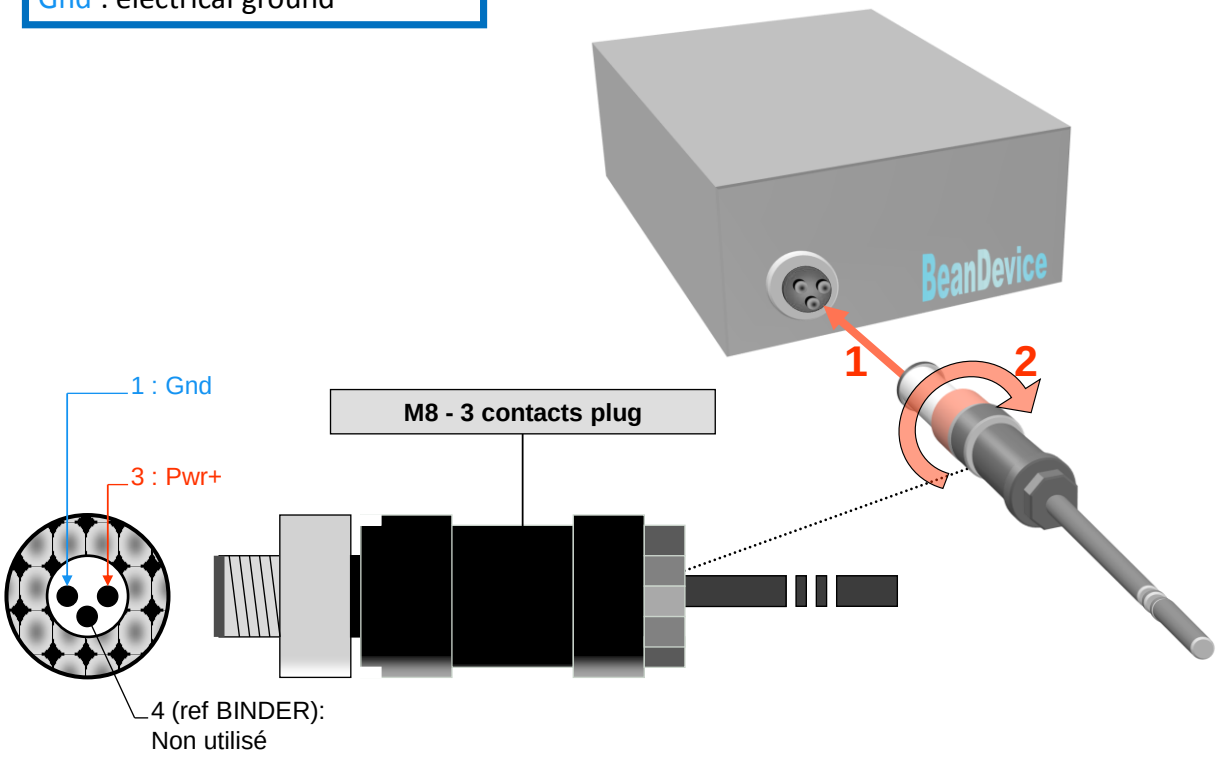
*For further information about the BeanDevice® autonomy please read the technical note **TN_RF_002 "Current consumption in active & sleeping mode on BeanDevice® products (wireless sensors)"**.*

10.1 ABOUT THE EXTERNAL POWER SUPPLY

Caption:

Pwr+ : power supply 8-28 V DC

Gnd : electrical ground



The BeanDevice® can also be powered by an AC-to-DC adapter ***8-28Volts***. The power adapter can be used for recharging Lithium-Ion battery or to power supply continuously the BeanDevice®.
A M8-3Pins standard plug is used for connecting the power adapter to the BeanDevice®.

Only the M8 plug is fully sealed, the power adapter is not sealed.

10.2 SOLAR PANEL KIT

You can use a solar panel kit:

- ✓ ***Battery Charge controller***
- ✓ ***High rate valve regulated sealed lead acid (VRLA)*** : these batteries have been developed for long term operation in harsh environments
- ✓ ***Solar Panel:*** the size of the solar panel depends on the average consumption of the BeanDevice®

You can buy a Solar Panel Kit from these providers:

www.tyconpower.com

http://www.solar-electric.com/chco.html

http://www.futurlec.com/Solar.shtml